The Universe, Big Bang Theory & Evolution of the Universe

1. The Universe

Definition

The Universe = **all existing matter + energy + space**.
It includes:

- **Physical components:** subatomic particles → stars → galaxies → superclusters
- **Non-physical components:** light, gravitation, space

Scale

- **~100 billion galaxies**
- Each galaxy has **~100 billion stars**
- The Milky Way has **100–400 billion stars**

2. Basic Astronomical Terms

Cosmos – another word for Universe

Cosmic – relating to the Universe

Cosmic Rays

- Highly energetic particles travelling close to the speed of light
- Can cause **gene mutations → cancer**

Cosmology

- Study of **large-scale properties** & evolution of the Universe

Astronomy

- Study of **celestial objects & phenomena** beyond Earth's atmosphere
- Includes: stars, planets, solar wind, gravitational waves, etc.

3. Big Bang Theory

The prevailing model of Universe origin

13.8 billion years ago

- The universe originated from a **single point** of *infinite density + temperature*
- The universe has been **expanding in all directions** since then
  (Supported by Hubble's Law)

4. Evolution of the Universe

Time After Big Bang	Temperature	Event
10^{-43} sec	10^{32}°C	**Inflation**: The Universe expands from the size of an atom to a grapefruit
10^{-32} sec	10^{27}°C	Hot soup of electrons, quarks, particles
10^{-6} sec	10^{13}°C	Quarks → protons + neutrons (baryogenesis)
3 minutes	10^{8}°C	Still too hot → no atoms; light cannot pass
3 lakh years	10^{3}°C	**Recombination**: atoms (H, He) form; first light emitted
1 billion years	–200°C	Gravity forms galaxies; first stars form
15 billion years	–270°C	First stars die → heavy elements created → new stars & planets

5. Big Crunch (Possible End of Universe)

- The universe may expand to its maximum size, then **collapse**
- Becomes dense & hot → ends in a state similar to the beginning
- Results in **high-density single point** again

(Note: This is theoretical, not observed.)

6. Accelerating Expansion of the Universe & Dark Energy

Observation (Hubble's Law)

Galaxies are moving away, and their **recession velocity keeps increasing** → expansion is accelerating.

Implications

- The universe will become **colder**
- Matter spreads farther apart
- No collapse (opposite of Big Crunch scenario)

Dark Energy

- Unknown, hypothetical form of energy
- Fills **all of the space**
- Causes **accelerated expansion**
- Began dominating the Universe **~5 billion years ago**

CHECKPOINTS

- Universe age = **13.8 billion years**
- Galaxy count ≈ **100 billion**
- Milky Way stars = **100–400 billion**
- Cosmic rays → **mutation + cancer**
- Big Bang = **high density + high temperature** single point
- First stars formed = **1 billion years** post Big Bang
- Recombination (first light) = **3 lakh years**
- Dark energy dominated = **5 billion years ago**
- Universe expansion = **accelerating**, not slowing

MCQs

1. Which of the following best describes the Universe?

A. All galaxies in space
B. All existing matter, energy, and space
C. Only stars and galaxies
D. Only the observable part of the cosmos

Answer: B
The universe includes everything—matter, energy, and space.

2. Cosmic rays are primarily:

A. Photons travelling at light speed
B. Highly energetic atomic nuclei or particles
C. Streams of electrons emitted by stars
D. X-rays from black holes

Answer: B
They travel near light speed and cause gene mutations → cancer.

3. The Big Bang state was characterized by:

1. Infinite density
2. Extremely high temperature
3. Presence of hydrogen atoms
4. Slow expansion

Select the correct answer:
A. 1 and 2 only
B. 1, 2, and 3
C. 2 and 4 only
D. 1, 2, and 4

Answer: A
Hydrogen formed 3 lakh years later; the early Universe expanded extremely fast (inflation).

4. The "Recombination Era" refers to:

A. Formation of galaxies
B. Formation of first atoms
C. Formation of heavy elements
D. Formation of cosmic rays

Answer: B

5. Dark energy is responsible for:

A. Fusion reactions inside stars
B. Formation of black holes
C. Accelerating expansion of the Universe
D. Slowing down the expansion of the Universe

Answer: C

6. Milky Way is best described as:

A. An elliptical galaxy
B. A barred spiral galaxy
C. An irregular galaxy
D. A ring-shaped galaxy

Answer: B

7. Which statement about the "Big Crunch" is correct?

A. It is an observed phenomenon
B. The universe will expand forever
C. The universe may collapse back into a dense point
D. It describes the formation of black holes

Answer: C